AFRL-ML-WP-TR-1999-4011

EXPLORATORY NONDESTRUCTIVE EVALUATION (NDE) RESEARCH FOR ADVANCED MATERIALS AND PROCESSES

VOLUME 3 : INTERACTIVE MULTIMEDIA COMPUTER BASED TRAINING (IMCBT) FOR NONDESTRUCTIVE EVALUATON/ INSPECTION (NDE/I) PERSONNEL

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JULY 1998

FINAL REPORT FOR 07/01/1995 – 04/30/1998

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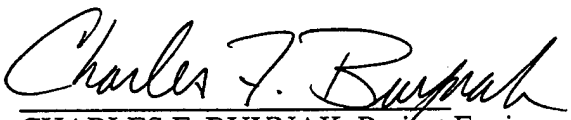

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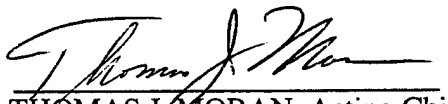

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	JULY 1998	FINAL REPORT FOR 07/01/1995 - 04/30/1998

4. TITLE AND SUBTITLE
EXPLORATORY NONDESTRUCTIVE EVALUATION (NDE) RESEARCH FOR ADVANCED MATERIALS AND PROCESSES; VOLUME 3: INTERACTIVE MULTIMEDIA COMPUTER BASED TRAINING (IMCBT) FOR NONDESTRUCTIVE EVALUATION/INSPECTION (NDE/I) PERSONNEL

5. FUNDING NUMBERS
C F33615-95-C-5225
PE 62102
PR 4349
TA 44
WU 01

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
BOEING INFORMATION
SPACE & DEFENSE SYSTEMS
P.O.BOX 3999
SEATTLE, WA 98124

8. PERFORMING ORGANIZATION REPORT NUMBER
D950-10333-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
MATERIALS AND MANUFACTURING DIRECTORATE
AIR FORCE RESEARCH LABORATORY
AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AFB, OH 45433- 7734
POC: CHARLES F. BUYNAK, AFRL/MLLP, 937-255-9807

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFRL-ML-WP-TR-1999-4011

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Interactive Multimedia Computer Based Training (IMCBT) for Nondestructive Inspection (NDE/I) Personnel: Computer Based Training (CBT) is a highly effective method for industrial training that has been growing in popularity. Text, graphics, sound, movies and animation enhance the learning activity. Interactive Multimedia CBT (IMCBT) allows students to learn in an environment where the training material is presented on a computer workstation and uses student interaction and feedback in the learning process. This technology has been used in the aerospace industry for aircraft maintenance and flight training and is growing in many operation training areas. The cost of development of IMCBT material is significantly more expensive than traditional training material, but an hour of IMCBT material can contain more information than an hour of traditional training material since information is transferred faster and with higher retention. Because IMCBT delivers training at lower cost, the overall benefit of IMCBT has been found to be in the range of 40% to 60% cost savings. The application of IMCBT for NDE/I training did show an overwhelmingly positive acceptance of the incorporation of IMCBT for NDE/I personnel within existing training structures. A CD-ROM package called INSPECT (Interactive Student Paced Eddy Current Training) has demonstrated various advanced aspects of potential IMCBT lessons. The INSPECT CD demonstration was reviewed by Air Force and industry professionals, as well as a group of high school students to gauge novice response. The prototype was found to be appealing and to have significant potential as a useful teaching tool. A large majority of the professional reviewers stated they would like to have complete CBT modules like INSPECT for some aspect of their NDE/I training.

14. SUBJECT TERMS
Failure Analysis, X-ray, Imaging, Microfocus, Radioscopy, computed Tomography, Electronics, Composites, Area Inspection, Shearography, Interactive Multimedia Based Training, computer-Managed Instruction, Nondestructive Evaluation and Inspection

15. NUMBER OF PAGES
32

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

Interactive Multimedia Computer Training (IMCBT) for NDE/I Personnel. Technical effort in this program was supported by Stephen Newmark, Steve Durrett, Peggy Ferderer, Brad Fisher, Mike Jacobsen and Wilma Redhead of the Boeing Computer Based Training staff. Technical input on training material was provided by Sharman Jone and Charlie Raatz of Boeing QA and Measurement R&D organization. The Air Force NDI Training School, the Air Force NDI Program Office, Air Force Air Logistic Centers and Karta Technology are also acknowledged for their input of technical information, viewpoints, perspectives and review of the INSPECT CD. Special thanks are extended to Steve LaRiviere, manager of Boeing QA and Measurement R&D organization, for his support of the project. Likewise special thanks are extended to Steve Fain, Intern Vice Principal of West Seattle High School, teachers Ray Sweetser and Dan Peterson, and the high school students who participated in the evaluation of the IMCBT INSPECT CD.

DISCLAIMER

The information contained in this document is neither an endorsement nor criticism of any software applications, computer hardware, imaging instrumentation or other equipment used in this study.

EXECUTIVE SUMMARY

Boeing Defense & Space Group was awarded the "Exploratory Nondestructive Evaluation (NDE) Research for Advanced Materials and Processes" contract in 1995 to study improvements for NDE methods for evaluating aging assets, primarily aircraft, with the primary end objective to reduce the cost of maintaining these aging assets. The study involved three separate approaches, responsive to the three task elements contained in the Statement of Work. The first approach was to look at the use of high resolution computed tomography (CT) in failure analysis, the second was to study improvements in shearography, and the third was a demonstration of the use of interactive multimedia computer-based training for NDE/I inspectors. Because each task is distinctly unique, they are discussed in separate report volumes – collectively referred to as FAST: Failure Analysis, Shearography, Training. This is volume III, covering Training.

Computer Based Training (CBT) is a highly effective method for industrial training that has been growing in popularity. Text, graphics, sound, movies and animation enhance the learning activity. Interactive Multimedia CBT (IMCBT) allows students to learn in an environment where the training material is presented on a computer workstation and uses student interaction and feedback in the learning process. This technology has been used in the aerospace industry for aircraft maintenance and flight training and is growing in many operation training areas. The cost of development of IMCBT material, however, is significantly more expensive than traditional training material. This is because initial development costs are higher, as the development process takes longer and requires more resources. These developmental costs approach $40,000 per playing hour of instructional material. However, an hour of IMCBT material can contain more information than an hour of traditional training material since information is transferred faster and with higher retention. Because IMCBT delivers training at lower cost, the overall benefit of IMCBT has been found to be in the range of 40 to 60% cost savings. This program has investigated the application of IMCBT for Nondestructive Inspection (NDI) training and did show an overwhelmingly positive acceptance of the incorporation of IMCBT for NDE/I personnel within existing training structures.

The development of IMCBT material for NDI training incorporates more sophistication in CBT lessons than maintenance and flight training by including special elements which go beyond merely showing procedures. A demonstration CD-ROM package called INSPECT (INteractive Student Paced Eddy Current Training) has demonstrated various advanced aspects of potential IMCBT lessons in sections titled: Theory, Practice/Simulation, Testing, Glossary, Ask-the-Expert and Technical Order Reference which expand upon the basic information. The CD-ROM is designed to run on a multimedia PC, displaying images using 1024 by 768 resolution and 16 bit color. Because this program was to examine the potential use of IMCBT for NDI training, the prototype was created to demonstrate how a NDI CBT module might be assembled and then evaluated for future use; therefore, it was felt to be more important to cover all the CBT functions, even if lightly, than to spend all the effort in demonstrating only some of the functional areas.

The INSPECT CD demonstration was reviewed by Air Force and industry professionals, as well as a group of high school students to gauge novice response. The prototype was found to be appealing and to have potential as a useful teaching tool. The reviewers liked the quality of art work, the use of audio, and the use of motion graphics (animations) to depict the physical principles of NDI techniques. A large majority of the professional reviewers stated they would like to have complete CBT modules like INSPECT for some aspect of their NDE/I training. Aside from various "bugs" and various likes and dislikes in presentation, most of the critiques were about insufficient depth and coverage, which of course, would be completed for a final CBT module.

A number of lessons has been learned in the development of the INSPECT demonstration CD. 1) Authorware, by MacroMedia, the commercial software used for creating the lessons, is a suitable authoring program for general theory instruction, but does not contain enough power to generate proper simulations. 2) The physical principles of NDI techniques can be presented much more clearly using animation than in static figures. 3) Good animation can often depict an activity more clearly than video. 4) The quality of the artwork enhances interest in the material and is critical for displaying the layout and features of specific NDI instruments. 5) Video should be run at 16 bit color level. 6) The simulation of 3D motion NDI scanning activity using a mouse pad and video screen requires simplification of the real world conditions. 7) Combining all of the capabilities demonstrated in the INSPECT CD-ROM involves a more complicated navigation flow for the IMCBT material than has been used previously in maintenance and flight training.

1.0 INTRODUCTION

The use of interactive multimedia computer based training (IMCBT) for NDI training is becoming recognized as a very desirable instructional method. The reasons for moving to IMCBT are many, but foremost is the desire to improve the performance of NDI personnel through uniform, high quality instruction and higher information retention factors. IMCBT has been shown in industry to provide these benefits. Further, the delivery costs of IMCBT are much lower than conventional classroom training, offering direct cost savings.

Because the Air Force is involved with thousands of NDI personnel who require appropriate training, IMCBT training material for fundamental NDI processes is a worthwhile endeavor. The material will be widely distributed and used. However, the application of NDI also involves a number of special processes and operations that would benefit from IMCBT training material, although they may apply to only small specific groups. The desires of the Air Force NDI training community to have fundamental and specific training for both classroom and individual study impact the requirements for IMCBT. The following sections discuss the issues and recommend, where possible, directions for IMCBT development.

2.0 ADVANTAGES OF IMCBT

IMCBT has a number of advantages over conventional training. Table 2.1 lists the primary advantages with explanatory comments.

Table 2.1. Primary Advantages of IMCBT

Advantage	Comments
Student Paced	Students can move through the material at their own pace, spending greater time in areas that are unfamiliar and moving rapidly through areas already comprehended or of less interest.
Interactive	The lessons include activities to engage the student, retaining interest.
Animated	Dynamic and 3D concepts, that are difficult to follow on paper, can be easily shown with animation.
Systematic Testing	Testing and scoring with feedback to lesson areas are possible.
Set-up, Demonstration and Simulations	Videos, animation and interactive pictures can be used to demonstrate procedures or simulate test scenarios. This is particularly useful for "just-in-time" training.
References	Significant amounts of reference material can be included with the training material and accessed readily for technical details or remedial activity.

Various studies of IMCBT advantages have been performed over the last 20 years. The major cost savings documented appear in the form of reduced training time, reduced instructor time, elimination of travel and increased retention and performance. The delivery costs of IMCBT are much lower than traditional training, however, the development costs are much higher. There must be a sufficient volume of training needed to justify the development costs. Up until the last five to ten years, the advantages found were generally slight. As advancing computer technology has brought more capability to bear, the interest in IMCBT has increased and the advantages claimed have risen. Recent claims include: 50% gain in learning, 20 to 40% better consistency in lesson delivery and 50 to 60% better consistency in learning. Studies by companies using IMCBT have shown that they can reduce the overall cost of training. Savings of 20 to 80% with 40 to 60% being the most common have been measured. The Air Force IMCBT maintenance training courses for F-15 and F-16 were found to generate a 25 to 50% increase in knowledge, an 80 to 90% improvement in troubleshooting skills and a 25 to 1 return on investment.

The costs to develop IMCBT course material can run in the range of $40,000 per instructional hour of training material or more depending on the sophistication involved. Because IMCBT transfers information faster and with higher retention, lesson time is generally shorter than in conventional training. One hour of IMCBT training can represent 1.5 to 2 hours of conventional training. Of course, lower quality, cheaper CBT material may be produced, but this has associated risks. Less comprehensive courses may be incomplete, inexact or fail to hold the interest of the viewer. Failure to maintain interest or transfer information would essentially make the material worthless.

3.0 COURSE MATERIAL

3.1 Teaching Style

The Air Force NDI training school, as well as most other organizations experienced in training, are using some form of instructional system development (ISD) format. This might be referred to as a performance/goal orientation approach to training. In this approach, the learning objectives are defined and an assessment of the learning objectives is developed. Within the specific learning module, an objective of what the student is expected to learn is postulated. The instruction then provides the material necessary to learn the objective. Finally the student is tested on the objective. Each lesson module with an objective must have at least one question to test that objective. The course material can be segmented into a number of small objectives that are given in modules. The modules combine to form the complete course. This approach is a part of the ISD process advocated for training systems.

For IMCBT course material the use of ISD performance/goal orientation in the courseware design allows a flexible course to be developed. A large number of modules is created with various levels of background or acquired knowledge necessary to correctly complete the modules. Courses may then be constructed from the modules to train various levels of NDI expertise, from trainee to level I and level II.

Within the course of instruction, the IMCBT material uses 3D animated graphics and digitized video to convey physical concepts. This improves understanding and retention of concepts. The interaction requires the student to select items in order to proceed and keeps the student involved in the lesson. Additionally, the use of humor and break periods reduces fatigue and maintains the interest of the student. For high school graduate level students, educators have suggested that some sort of reward system within the course material be provided. For example, if recreational activities, such as computer games, are included in the education package, then the ability to utilize the recreational tools could be tied to performance in the training activity. Better test scores in the computer-based training course material would be rewarded with game access.

3.2 Instructional Material

Presently, each Air Force organization which performs training (NDI Training school, ALCs, etc.) has course material which is used for in-house training courses. The majority of the material is developed from in-house resources. T.O. 33B-1-1, "Nondestructive Inspection Methods," is used as a primary resource. American Society for Nondestructive Testing (ASNT) training materials are also used as resources. The instructors at the various facilities have developed the courses over time. The consistency of the material between Air Force locations is derived mainly from the reference to T.O. 33B-1-1. Otherwise, there can be considerable diversity in the course instructional material. Most organizations use an instructor presentation format with handouts for the students to follow along.

The Air Force also has Career Development Course (CDC) material for NDI, which is an independent study program. The AF NDI Training School has developed this material in a workbook fashion.

For the AFNDI training school, the instructional material is primarily geared to high school graduates. Age for airmen in training will be predominately around 18 years. It is not uncommon, however, to have remedial needs for students. For civilians at the ALC's and air bases, there will be a wide range of ages. Cultural backgrounds will vary greatly in the student population for both airmen and civilian courses. The course material that has been independently assembled by each of the various AF organizations performing training must satisfy the needs of those particular organizations. The delivery of that material must be geared to the audience. Care must be taken in the creation of computer based training such that the materials are relevant and acceptable to the cultural and age diversity of the trainees that may use the lessons.

3.3 Relevance of IMCBT

An alternative to the presentation of current course material for NDI training is the use of IMCBT material for NDI. The IMCBT material is taken from the present course instruction material (ASNT, AF NDI Training School, T.O. 33B-1-1, etc.) and reformatted to interactive multimedia presentation. In order to meet the wide range of needs in the Air Force for the NDI courses, the material must be broken down into modules that are suitable for the levels of trainee, such as level I and level II. Courses are assembled from the modules to meet the needs of each organization. When IMCBT material is employed, it may be used with an instructor or stand-alone. Instructor led IMCBT is used in a classroom situation allowing an instructor to interact with the students and use interactive models of physical principles or technique application via projection of images onto a classroom screen. Basic maintenance training courses work well in this format because the instructor can observe the new trainees allowing material emphasis to be tailored to the audience. In discussions with Air Force trainers at the AF NDI school and the Air Logistics Centers, there is a strong sense that an instructor be involved in the basic training class, but with modern instructional material available in IMCBT format.

In addition to the basic NDI training, a significant need for refresher training is recognized. This is driven by the recertification requirements of MIL-STD-410 for NDI personnel. Because of the need to maintain certified personnel in many methods, a person may be certified but not actually performing the tasks regularly. Refresher courses are essential for this situation so that the person can be recertified. A similar situation exists for reservists who may not have the experience of many inspections, yet must be skilled. Refresher course material in IMCBT format would be highly beneficial because the student could review material without requiring a full time instructor. Using the IMCBT modules, appropriate refresher course material could be assembled. Under an independent student paced computer based training system, the course material can be studied whenever it is needed.

Student-paced IMCBT uses similar material to instructor-led IMCBT except that the student uses the computer independently of an instructor. The IMCBT courseware for student-paced instruction is necessarily more carefully structured, with greater attention to detail than is required for instructor-led presentations.

4.0 IMCBT TRAINING COURSEWARE

4.1 Authoring Systems

The development of IMCBT requires a suitable authoring system to create the interactive computer training modules. An authoring system is a computer program that assists the instructional expert in building and developing the information to be displayed along with all the linking to provide a smooth flow through the material. The IMCBT material should be developed using a common authoring tool for computer based training. The authoring system must be able to export and import courseware elements in standard formats. These format requirements are defined in the AICC Guidelines and Recommendations Document AGR-007, "Courseware Interchange."

The authoring systems for training are often the same or similar to those used to create computer games. Over the past decade these programs have become very sophisticated in their ability to incorporate different forms of media and operate those forms effectively. Examples of commercial programs which can be used to create training material are: Authorware, IconAuthor, Toolbook, Quest, Supercard, Director, CourseBuilder, HyperStudio and many others. Authorware, by Macromedia, is the authoring program that is being used most heavily at The Boeing Company for training material.

This authoring program uses an iconic/flow control paradigm that employs icons to represent functions and interactions, and a flow to show links. This paradigm tends to be the speediest for material development relative to hierarchical object, hypermedia linkage, scripting language, card/scripting or cast/score/scripting paradigms.

4.2 Inspect CD

Under the Exploratory Nondestructive Evaluation (NDE) Research for Advanced Materials & Processes, a demonstration training CD was created using authorware. The CD was called INSPECT Interactive Student Panel Eddy Current Training. The goal in creating the INSPECT CD and using it for demonstration was to show various areas and capabilities that could be used in an IMCBT lesson and to evaluate the techniques used in creating CBT lessons for their effectiveness.

IMCBT courseware must contain a number of elements that can be accessed by the user. Table 4.1 shows an example of the coordination of material in the training package. These elements have been derived by examining the existing training material used for Air Force NDI training and discussions with parties interested in the desirable characteristics of IMCBT. The major sections under each NDI method include instructional material in theory, simulated practice with hardware and testing techniques, additional informational material in testing, expert answers to questions, field training, references and glossary of terms. The instructional material should be under a management control tool for course instruction. The additional materials would be accessible by individuals for informational purposes. The field training section could involve specific inspections that require certification and testing, such that management control of access may or may not be necessary.

Table 4.1. Training Package Content

Theory	The basic theory instruction modules are presented in this section. The theory modules include instruction levels for apprentice, Level I and Level II individuals.
Practice & Simulation	This section presents instruction modules that include the practical application of the theory with an instrument. Simulations of instrument inspection are available in this section. Ideally, the simulations will contain a database of typical flaws from which an instructor can select for student practice. The modules are developed for Apprentice, Level I and Level II skill levels.
Testing	The Testing section includes a number of questions that can be used by management for the creation of examinations. Testing is also included directly in the Theory and Practice sections of the courseware. The tests may be taken on a hardcopy printout or on the computer system itself.
Ask the Expert	This section contains frequently asked questions that deal with troubleshooting and specific expertise in examination. T.O. 33 B-1-1 would be a primary resource for some of the material in this section.
References	This section contains references useful to inspectors. TO's would be primary candidates to be included in this section
Glossary	A glossary of terms, taken from T.O. 33B-1-1, is included. This material should be accessible at any time from the other modules.
Field Training	This section contains specific field training activity. It could be used for "just-in-time" training. The section is built using information contained in the course instructional material

The courseware must be developed with a high quality level in order to succeed in providing superior training and retention over current training methods. High quality requires that care be taken in establishing criteria for a standardized appearance and feel of the IMCBT material. Key items that must be appropriately handled in a consistent manner throughout the courseware include menu layouts, navigation aides, color schemes, graphics quality, video quality, use of sound, and fonts. IMCBT that contains modules that do not conform to a uniform presentation package will be confusing to the user and may result in poor retention. Continuing student interest is a very critical issue with IMCBT. This is accomplished by the engaging quality of the combined graphics, sound and video used. Additionally, the developers of IMCBT use appropriate interactivity and humor to retain interest and increase retention. It may be difficult to use humorous explanations that work across the cultural and age diversity of the Air Force workforce. Experience with similar broad based training material by the courseware developer would be an advantage. Experience with electronics training using computer based instruction also indicates that completely student-paced instruction is somewhat less effective than the combined instructor/computer based instruction for maximizing retention when teaching new subject matter to high school graduates.

The IMCBT approach and authoring systems offer many ways to deliver information to the student. The INSPECT demonstration lesson CD-ROM incorporates a number techniques. Table 4.2 lists the content areas contained in the CD-ROM and the capabilities that are being

demonstrated. The versatility of the IMCBT for training allows it to be applicable for introductory training, refresher training, general reference, and just-in-time training.

Table 4.2. INSPECT CD-ROM Content Areas

Content Area	Capabilities Demonstrated
Theory	Lesson flow - interactive student pacing Realistic depiction of physical principles using animation Interaction with the learning activity for interest retention Testing during a lesson
Practice/Simulation	Instrument feature display Animation of instrument response Test setup procedures Inspection scanning practice
Testing	Questions and test scoring
Glossary	Searching method for definitions Ability to check terminology and return to lessons
Reference	Search technical areas for information Presentation of information in text and video format
Ask the Expert	Detailed technical answers with standard figures
Tech Orders	Imbedded technical order text

A critical parameter in the development of CBT material is the selection of the resolution detail. In this effort 1024 x 768 pixels were selected as the desired resolution. This high-end resolution was selected to allow greater detail to be included in the images displayed. Drawbacks to using 1024 x 768 are that the lessons are larger packages (relative to 640 x 480 by over a factor of 2), more costly to produce and require suitable hardware that can display the CBT. On the other hand, the high resolution allows more flexibility for the producer to include detail, and suitable PC hardware is commonplace. In the INSPECT demonstration lesson, the simulation of the eddy current instruments required the high resolution format in order to include the instruments and text descriptions of the features in a clear, useful format on the screen.

4.3 Lessons Learned

The development of a demonstration CD-ROM included a variety of techniques and allowed a number of lessons to be learned:

1) The physical principles of NDI techniques can be presented much more clearly using animation in an IMCBT lesson than in static figures. While static figures are 2-dimensional, the IMCBT figures can show motion and, therefore, can demonstrate the 3-D characteristics of the physical parameter under study. This ability to more clearly represent physical reality results in faster comprehension by the student, thus reducing the overall time required to present material.
2) Good animation can often depict an activity more clearly than video. Although video is useful, in many cases the depiction of a test or configuration can be more clearly identified using the vivid rendition of reality in an animation.
3) Quality of the artwork (color and detail) enhances interest in the material and is critical for detailed features in instruments, such as panel displays. Video should be

run at 16-bit color level, which is capable of displaying over 65,000 colors to retain the quality level.

4) Authorware is a suitable authoring program for general theory instruction, but does not contain enough power to generate good simulations. For simulations, a more powerful scripting authoring language would be preferred. In the demonstration CD-ROM Beta Version the eddy current simulation scanning only used one-dimensional motion of the probe (horizontal translation). Two-dimensional motion (horizontal and vertical) is possible to simulate with Authorware but the simulation would still lack certain realistic characteristics that are desired by instructors.
5) The simulation of 3D motion NDI scanning activity using a mouse pad and video screen requires simplification of the real world conditions. In the real world all motions in 3 dimensions affect the inspection results. On a computer screen using a mouse and pad, only two dimensions can be used. This necessarily restricts the realism in the simulation. Nevertheless, for introductory level effort, the simulation can be of considerable value. The goal is not to replace the complete NDI system with a computer simulation, but rather to educate.
6) Combining all of the capabilities demonstrated in the INSPECT CD-ROM involves a more complicated navigation flow for the IMCBT material than has been used previously in maintenance and flight training. In the NDE IMCBT effort, considerable freedom to move between lesson, references and practice/simulation was desired. This can complicate the programming to assure that the lesson returns to the appropriate location when the student runs far afield of the starting point. In the past, maintenance and flight training have been simplistic linear lessons which are easier to program.

In addition to the lessons learned about IMCBT creation, a questionnaire survey was used to poll potential users of IMCBT systems about the prototype CD-ROM. The survey was distributed to NDE technicians, engineers and managers in the Air Force and industry along with the INSPECT demonstration CD-ROM. Both partial and complete replies were received for a total of 30 responses. Boeing was also interested in the response of novices since IMCBT technologies could be used for initial training of new Air Force members. To gauge novice response, Boeing provided copies of the CD-ROM to students in computer classes at West Seattle High School, in Seattle, Washington. West Seattle High is a large urban school with a very diverse ethnic mix in the student body. The students participating reflected this diversity and are likely to be representative of the technologically-aware individual that the Air Force recruits. Students evaluated the contents of the CD ROM as part of a regular computer class and filled out the same survey form as used by the Air Force and industry professionals. A total of 28 surveys was returned from the students.

The survey asked for overall impressions of artistic features in the demonstration courseware, such as animation, audio and art quality. Questions were asked about specific lesson features such as the sections on NDE theory and expert answers to questions. The poll also asked about user interactions such as types of test questions and the lesson navigation method. Reviewers were asked to rank the possible uses for IMCBT and whether more IMCBT lessons were of interest to them.

The responses were generally favorable from both the AF/industry and students. Figures 4.1 to 4.8 are "stacked" bar charts showing, in percentages, the responses to survey questions which asked the reviewer to rank (liked, OK, did not like) the various features and performance of the INSPECT CD. Figure 4.1 shows the results of the combined AF/industry and student responses to the overall opinion of the demo. Figures 4.2 and 4.3 show the same information, but with the AF/industry responses and student responses shown separately for comparison. Figures 4.4 to 4.8 show the responses to other questions asked – again, comparing the AF/industry responses to the student responses.

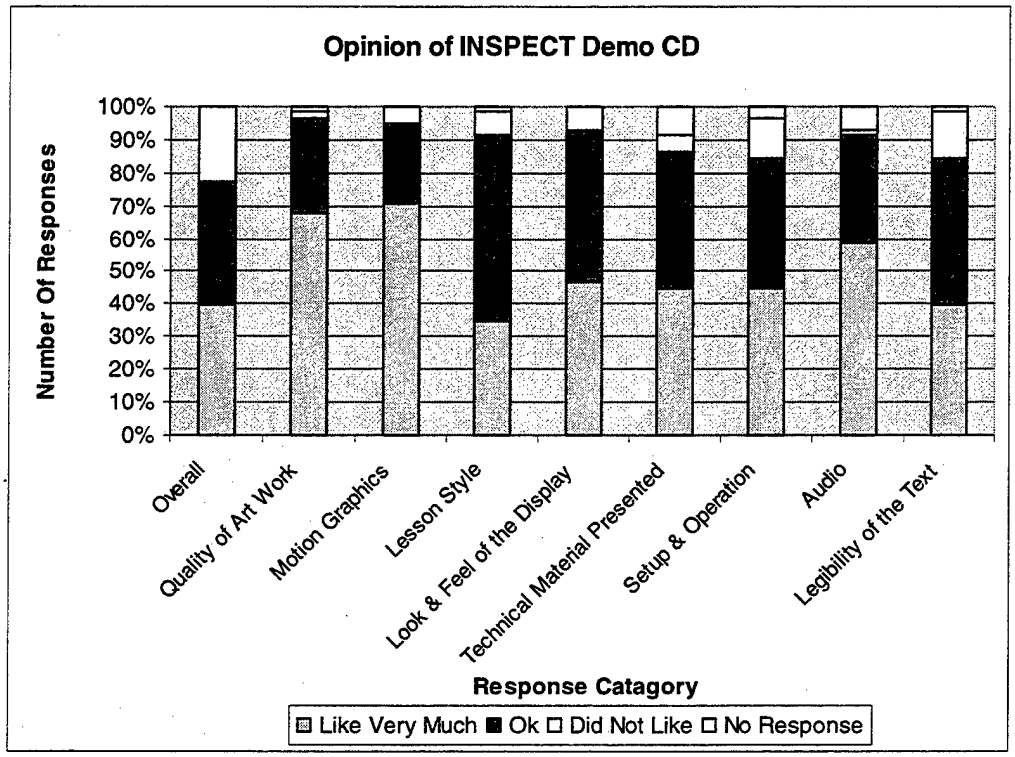


Figure 4.1. Combined Overall Opinion of INSPECT CD

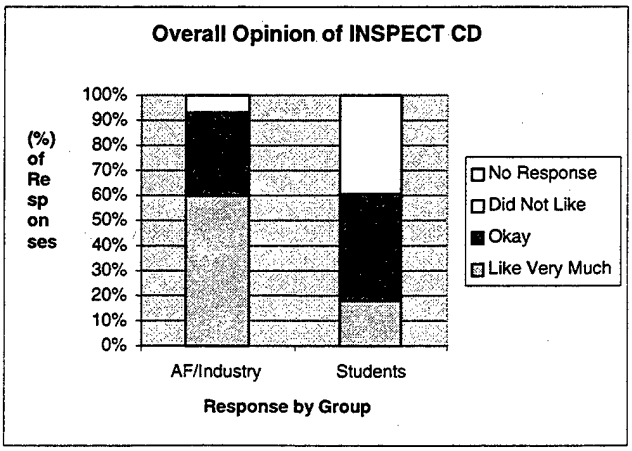


Figure 4.2. Overall Opinion of INSPECT CD – AF/Industry vs. Students

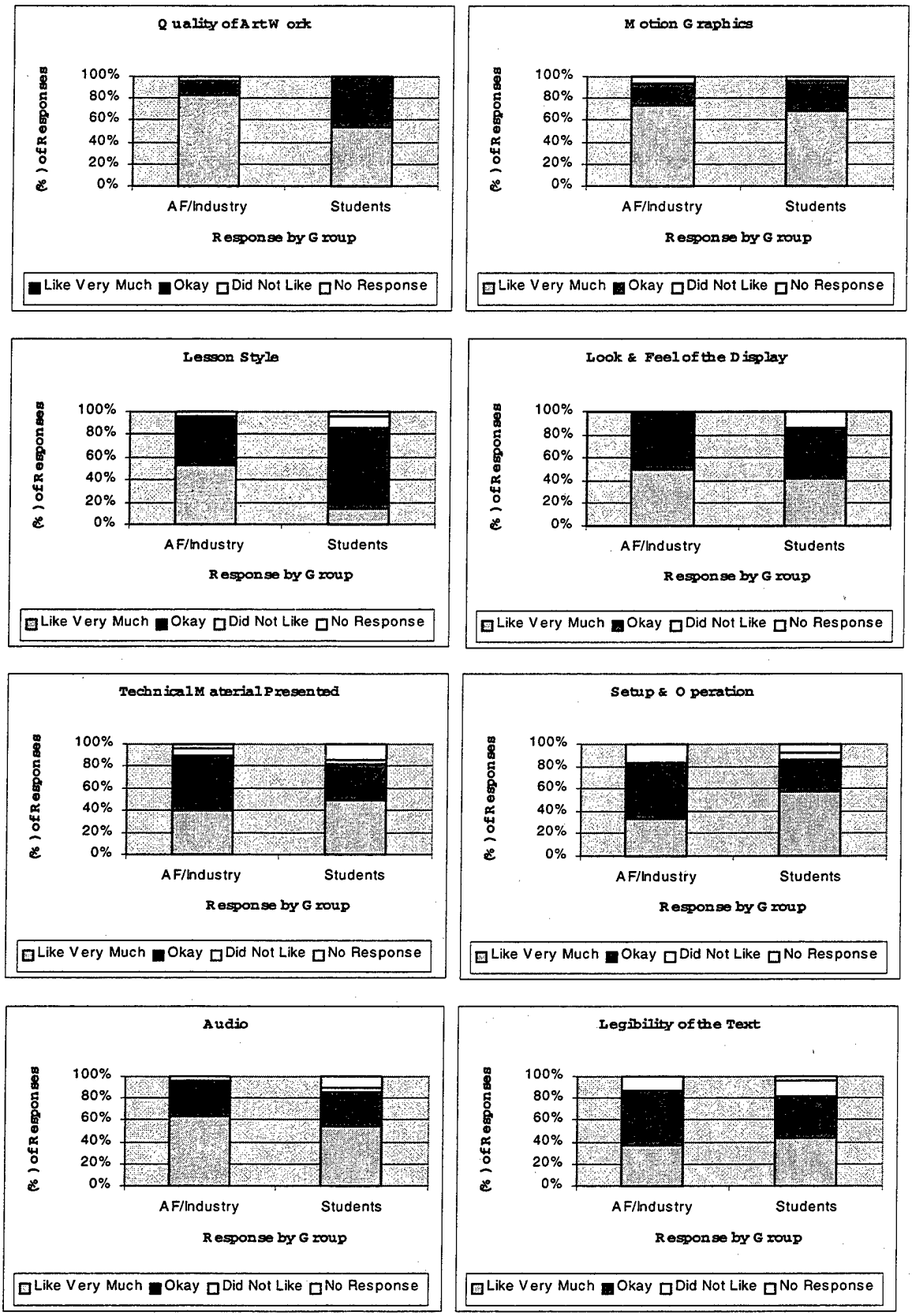
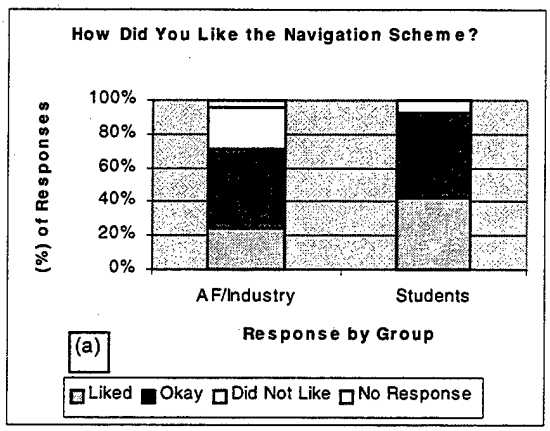
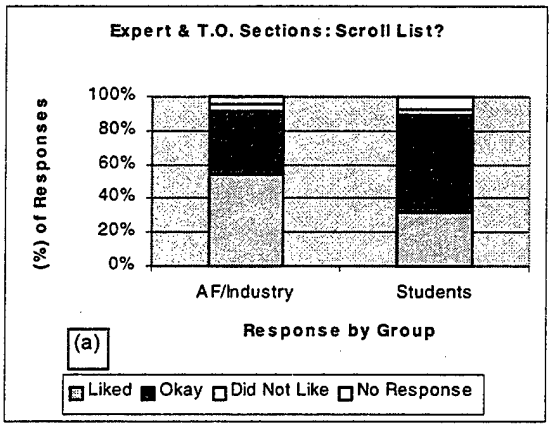
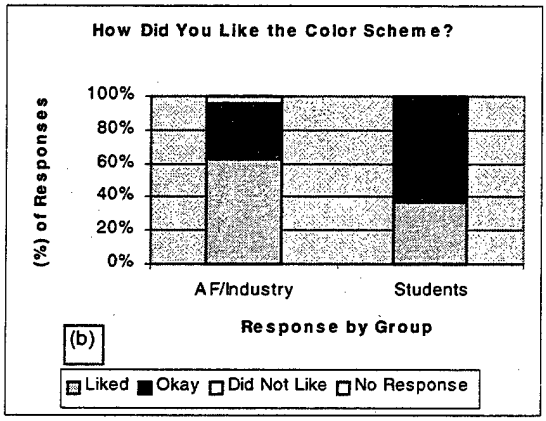
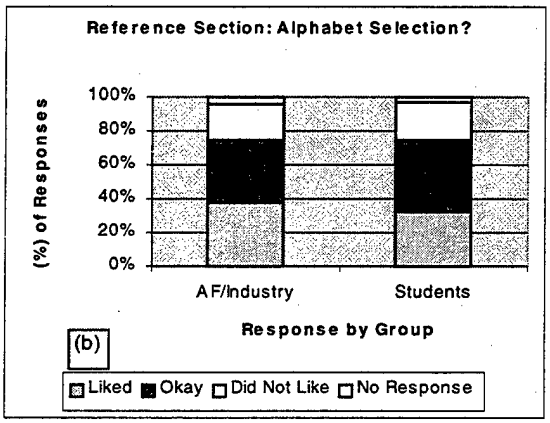


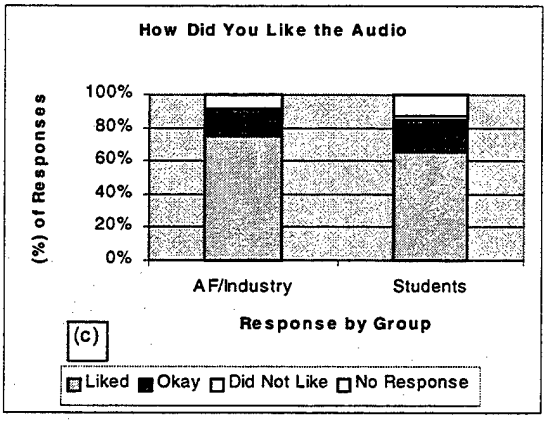
Figure 4.3. Results of Opinion Catagories of INSPECT Demo CD











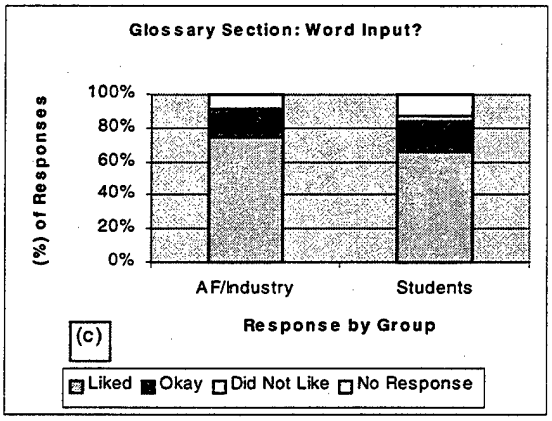


Figure 4.4. Responses to Navigation, Color and Use of Audio within the INSPECT CD

Figure 4.5. Responses to Glossary, Expert & Reference Section of INSPECT CD

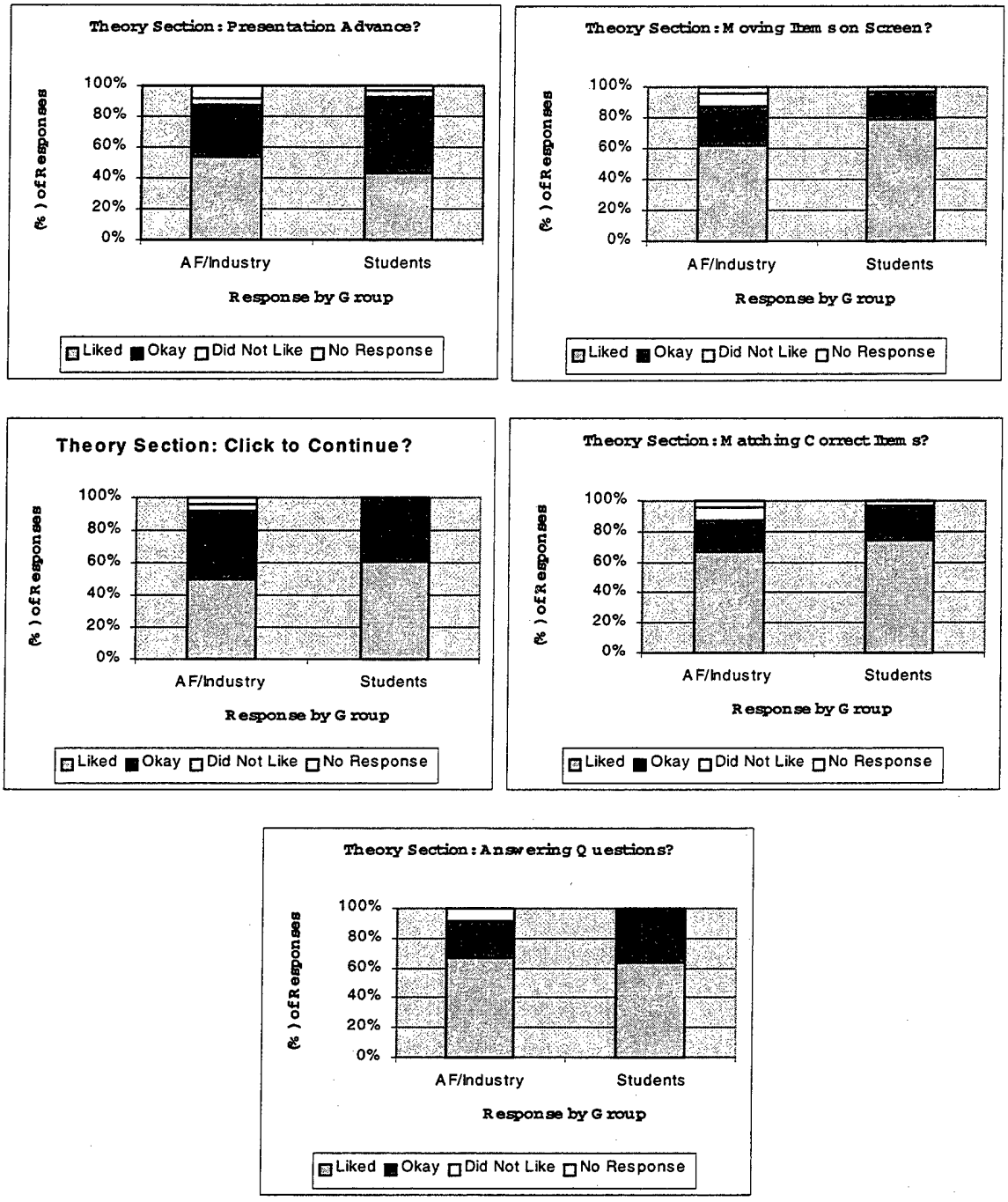


Figure 4.6. Responses to Theory Section of INSPECT CD

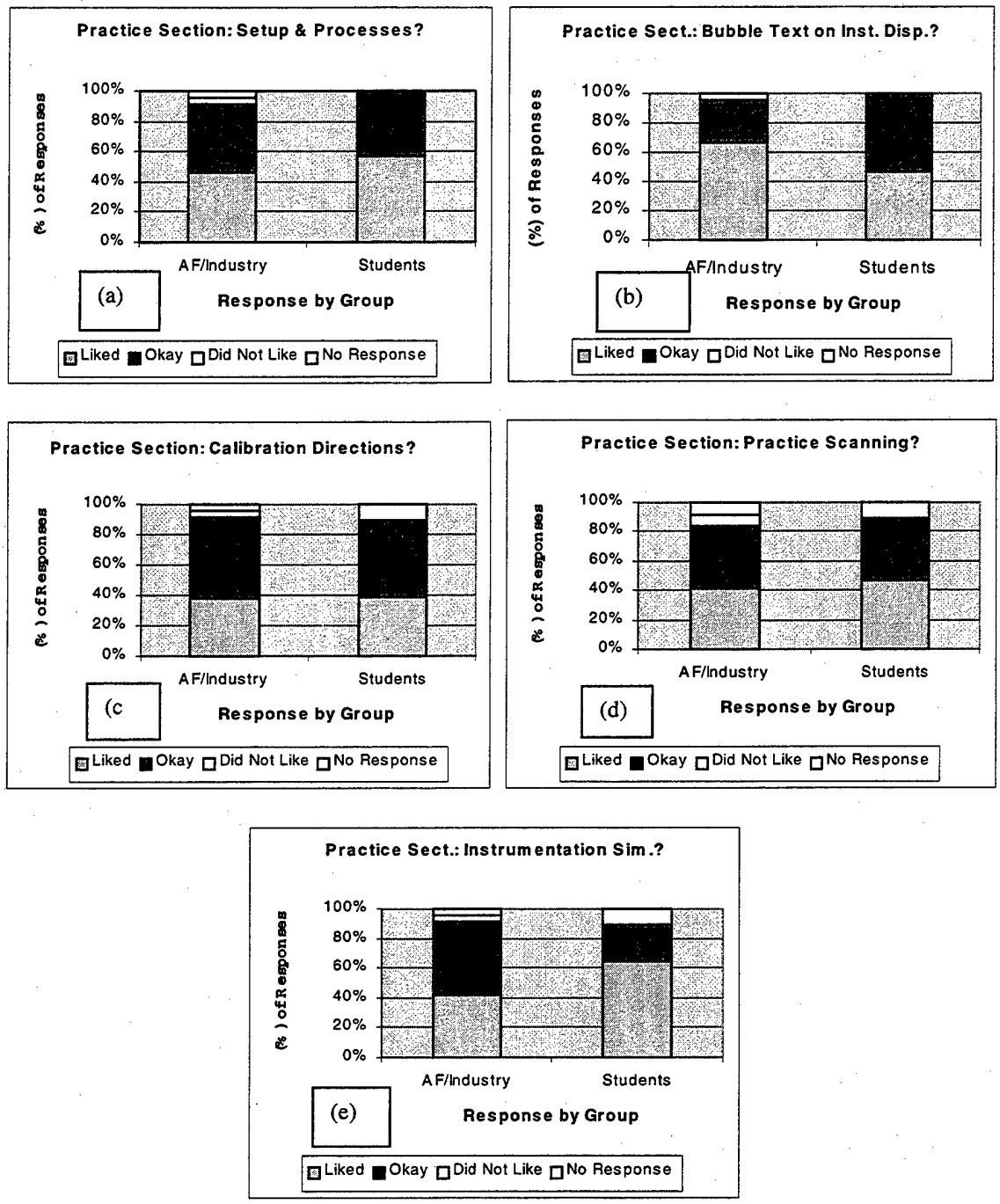


Figure 4.7. Responses to Practice Section of INSPECT CD

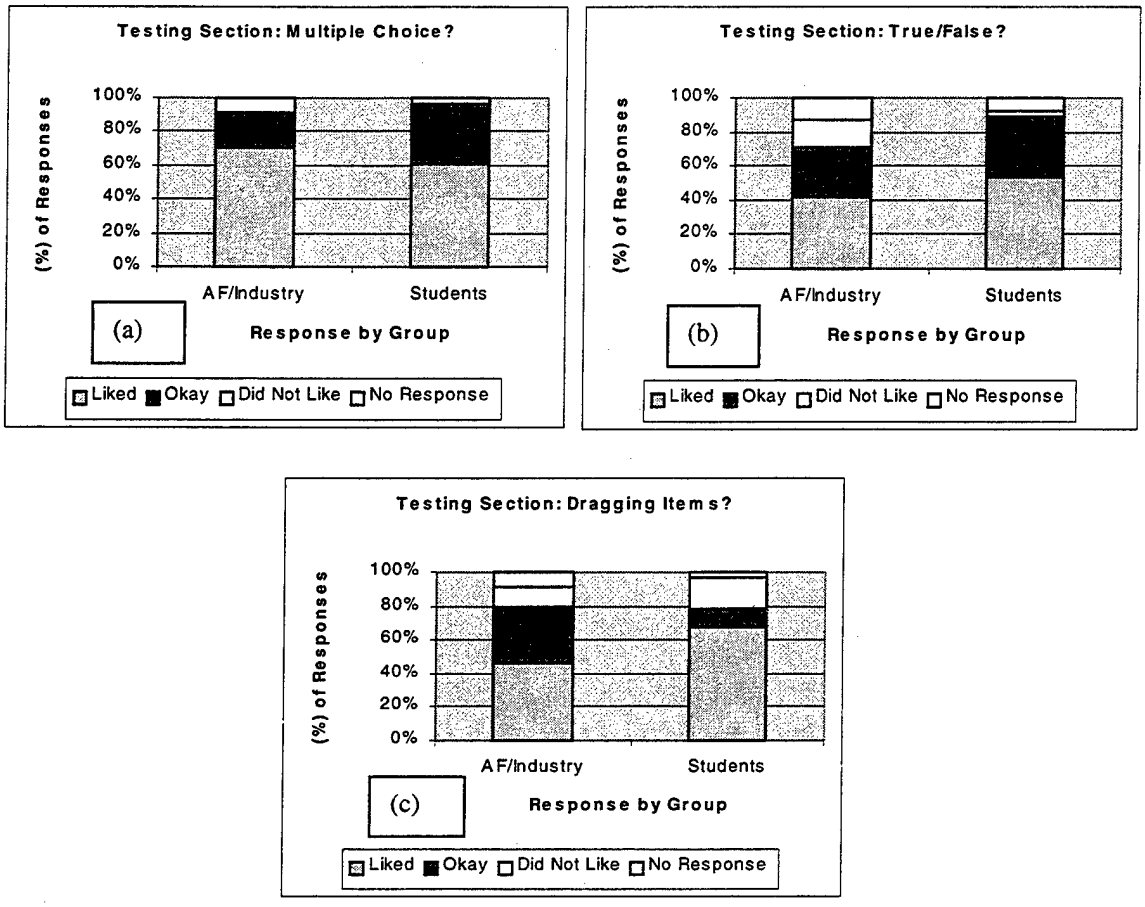


Figure 4.8. Responses to Testing Section of INSPECT CD

In general, the AF/industry reviewers were very interested in seeing more lessons on CD-ROM and felt the best uses of such material were for student-only training on theory fundamentals. Somewhat less interest was displayed for the use of IMCBT in teaching advanced material and in refresher courses. The sections on theory and student self-test were rated highly as were supplemental reference sections. The practice section was not rated as highly. This was due to particular complaints about the way in which the section worked in the current demonstration. The complaints are traceable to the simplistic level of simulation that was available. Generally, comments were enthusiastic about the idea of having a practice section with realistic animation for the student to interact with. Reviewers were interested in having a highest possible degree of reality in the practice section.

The major complaints with the CD-ROM centered on the scheme for navigating between screens in the course and on inconsistencies in presentation and use of audio and graphics. A stable and comprehensive set of navigation buttons on each screen would eliminate many complaints. Another important consideration in any new lessons would be to pay close attention to the look and feel of each screen. Very high consistency in audio, graphics, text and user response mechanisms such as icons, menus, mouse clicks and keystrokes would eliminate most of the negative comments received. Close attention also needs to be paid to

user cueing. Respondents were not always sure when or how they were expected to respond to the lesson.

A few, contradictory complaints were received about the level of technical detail included in the demonstration lesson. Some reviewers thought the course to be too technical and others thought it to be not technical enough. This is probably due to the differing educational and experience levels among the reviewers. This can be addressed by creating a number of modules of increasing complexity or by providing supplemental materials of increased sophistication within the lesson.

The students' responses were generally positive also. There was general agreement that the technology could provide an interesting, useful training experience. Perhaps reflecting their unfamiliarity with the material, the students identified the best uses of the CD ROM to be in OJT and fundamental training with an instructor present. Students were enthusiastic about the level of interactivity displayed in the Theory, Practice and Testing sections. The audio portion of the presentation was given high marks, as was the motion graphics used within the demo. As with the NDI experts, there were many negative comments about appearance items such as text font and size. Variations in navigation aids such as buttons and arrows drew uniformly negative response. Students also identified limitations in the Glossary, Reference, Ask the Expert and Tech Order sections as being irritants. There was a wide variety of opinion about the effectiveness of the color scheme – the majority thought it was ok, but most also thought it could be "livelier".

These responses indicate that the students were very receptive to the concept of IMCBT and would be sophisticated consumers of the generic technology. If these students are typical of new enlistees, novice Air Force users of IMCBT will be very sensitive to the packaging and presentation of the training material. If the material is carefully and professionally produced in a highly integrated, complete and engaging style, such persons will respond well to it and be able to focus on the content.

5.0 HARDWARE PLATFORMS FOR COURSEWARE DELIVERY STATIONS

The platform on which the training programs will be used is an important consideration for the development of the IMCBT lessons. This section presents hardware platform recommendations for running CBT courseware. The recommendations presented here are based on the AICC (Aviation Industry CBT Committee) recommendations (1). They represent a good, standardized approach not only to hardware platform recommendations but other aspects of CBT as well.

Today's desktop computers are rapidly evolving. What is common today was advanced yesterday and will be out of date tomorrow. This means that when defining a new platform for a particular application, the specifications should not be limited to the minimum that will accomplish the job. With an obsolescence factor of 3-5 years (and decreasing), the hardware investment should be extended as long as possible. The positive side of this is that as processing power and other performance attributes are increasing, overall cost is gradually decreasing. Care must be taken not to purchase expensive components which do not add value to the particular application, such as purchasing a very expensive sound card capable of producing high quality sounds for a musician, but not required for CBT work.

The selected system should be sufficiently flexible to allow different software applications to be run and to allow for user customized installations (e.g., stand alone or network operation). In addition, the system should be sufficiently expandable so that courseware or installation upgrades can be made at minimal costs. In other words, sufficient expansion capability should be planned into a system purchase to maximize the time between new system purchases.

It is recognized that a variety of computer systems exists already at the ALCs, training centers and Air Force Bases. However, IMCBT places a higher demand on system resources such as memory, disk space, video, sound and processing speed. The recommendations presented here are considered to be nominal for new hardware acquisitions. Older systems perfectly capable of handling word processing and other low intensity applications may not be capable of running CBT courseware. It is feasible to utilize existing systems provided they meet the general criteria as presented here. However, care must be taken if component upgrades are necessary. The cost of upgrading should be compared with the cost of a new system. The upgrade path is not necessarily the least expensive in the long term.

5.1 Platform Usage: Standalone or Networked, Portable or Stationary

The issues of connectivity and portability of the selected hardware platform are based on the preferred usage of the applicable CBT courseware by the personnel managing and administering the training, as well as the logistics and facilities where the training is to take place.

Standalone platforms have no connectivity to other computers. The software applications must be installed on the system's hard drive or run from a CD-ROM player; any data must be

removed via floppy disks or other removable storage device. This would be appropriate for a small classroom, or individual stations including portable laptops to be used in the field and situations where it is not cost effective to implement networking.

Standalone platforms are a reasonable way to introduce instructor-led CBT into a facility. It requires only a single computer with the addition of a digital overhead projection system such as an LCD panel projector. The courseware modules can be assembled so that the instructor can utilize them as lecture support data. This could include graphics, simulations, video, etc. The instructor has the choice of using the chalkboard or displaying pre-written notes. There are even electronic "white board" devices which use a computer and projection system to display what is written on them. The instructor-led method basically uses the CBT system as a graphical support tool for the presentation.

Networked platforms have the advantage of sharing information quickly and being managed from a central source. Courseware can be distributed and administered from a central source. Centralized control can include student administration and testing. This not only reduces the individual system's hard disk requirements, but also allows the instructor to quickly build courses and tests and distribute them more easily with greater control. When student-paced instruction is the intended primary usage of the installation networking should be strongly considered.

Laptop systems may be desired for remote operations such as working in the field, student working outside the classroom, etc. The use of docking stations with the portable systems would allow them to be used with a larger video display and network accessibility. Although costs are somewhat higher per station, this setup is ideal for the facility that requires both field work and classroom student applications.

5.2 Platform Components

The following discussion covers the basic component issues concerning a hardware platform for CBT and follows the recommendations of the Aviation Industry Computer Based Training Committee (AICC), except where noted. The PC is the most ubiquitous platform and offers a variety of hardware and software options, therefore, it is the recommended platform of choice. The discussions that follow are based on equipment that is available now (at the time this document is published) with some look to the future. However, this information should be updated based on currently available hardware and the thoughts discussed earlier in this section.

5.2.1 CPU (Central Processing Unit)

The CPU is the "brains" of the computer and for the most part determines the speed of operation - although other factors such as disk accessing and video processing will affect operation. The AICC recommends a 200 MHz Intel Pentium-based processor as minimum, with 300 (or faster) MHz Pentium II preferred. The current evolution in CBT courseware is moving to the use of 3D graphics, real-time simulation, and advanced multimedia – all requiring a faster CPU for smoother operation. If the end user intends to maintain and keep

up with future CBT packages, the 300 MHz recommendation would provide a better long-term investment, hedging against the associated high rate of hardware obsolescence.

Bus architecture is an important consideration in computer systems. The recommended standard at this time is a ISA(EISA)/PCI bus combination. ISA is required because there is still a number of 16-bit expansion cards in use and on the market, and because it has been the standard for some time. However, the PCI local bus has becoming the industry standard for new computers. PCI is a standard that was developed by Intel and is utilized by the Pentium processor. It offers significantly higher bus rates for video and hard drive performance. Current configurations have pushed these bus speeds up from 66 MHz to 100 MHz. For a platform to be used for CBT applications the AICC recommends a motherboard configuration with at least seven card slots. New computers are typically configured with five to seven slots of which three to four slots are PCI.

5.2.2 RAM (Random Access Memory)

The recommended minimum is 64 MB for a Windows 95-based operating environment. Windows 95 will operate with a minimum of 8 MB of memory, but there is a significant improvement in performance with RAM greater than 8 MB. For running multimedia applications, 64 MB or more are preferred due to the increased amount of high-resolution graphics, 256 and greater color display, complex simulations, digitized video and sound to be processed. Future software and courseware are anticipated to use even more memory. Memory costs have decreased dramatically and are at an all time low. Additional memory is now one of the best values, cost wise, for increasing performance.

5.2.3 Hard Drive

The only AICC Hard Drive recommendation is to use a local hard drive. The size of the hard drive is determined by the usage requirements, that is, the amount of software, which includes system, courseware and other application files, and data to be stored locally. Stand alone systems will require more disk space than networked systems, which can download files from a file server.

New desktop computer systems commonly contain hard drives from a low of 2 GB (2,000 MB) to 8 GB; whereas, just a couple of years ago 250-MB hard drives were considered "large" drives. Like RAM, the cost of hard drives has decreased dramatically and the sizes have increased rapidly – mostly to accommodate the ever increasing size of software applications. Older systems can be upgraded, however, the type of disk controller should be examined for compatibility with a newer hard drive. Most PCs built within the last 5 years use some form of IDE controller interface, Enhanced IDE (EIDE) and Ultra IDE being the standard for new equipment. The SCSI standard is the other main alternative. The SCSI interface can be used for other devices besides hard drives and works by "daisy chaining" multiple devices. SCSI hard drives have traditionally been much faster and larger in terms of storage capability, but are generally more expensive. With the enhancements to the IDE interface, combined with lower cost, IDE hard drives are very competitive with SCSI hard drives.

5.2.4 Video

The discussion of the video portion of the hardware platform falls into two areas, the video controller card and the display monitor. The video display portion of the platform is one of the most important components, since this is the primary interface with the user. If the video display causes eyestrain or is not appealing to the user, the CBT courseware will be of little value. Therefore, good judgment should be used when selecting the appropriate video display hardware.

The AICC recommended standard for the display monitor is 20" (diagonal measure) screen size, non-interlaced, multisync, with a horizontal scan rate of 31-64 kHz and a 75 Hz vertical sync or refresh rate. Non-interlaced, multisync monitors are generally standard equipment today. The recommended 20" screen size is not common yet; however, prices continue to drop in that area. More common now are 17" monitors, which are very cost effective and can deliver the same performance as the 20" monitors with less viewing area. The typical 15" monitor can also deliver similar performance characteristics, but the viewable cross-screen dimension can be as little as 12.5 inches - which is not adequate to display high-resolution graphics without eyestrain.

Screen flicker can be another source of eyestrain which is reduced with higher vertical sync or refresh rates. The accepted minimum is 72 Hz. A measure of the amount of data the monitor can handle without distortion is its bandwidth, calculated as follows: horizontal pixels x vertical pixels x refresh rate = pixel speed; pixel speed x 1.5 (for overhead) = acceptable bandwidth. Therefore, for a monitor set at VGA resolution (640x480 pixels) with a refresh rate of 72 Hz, the video bandwidth is ~33 MHz; for a display resolution of 1024x768, the necessary bandwidth increases to 85 MHz. Another parameter to take into account is the dot pitch, that is, the center-to-center dimension of the pixels. This measurement is one factor in how coarse the display appears. The smaller the dot pitch, the better the graphic appears. Many monitors now offer a dot pitch of 0.26 to 0.28 mm, which is quite acceptable. One of the last monitor parameters to be aware of is color depth, that is, how many colors can be displayed. Here again, most monitors available today should be capable of supporting at least 16 million colors. A side issue of color depth, but equally important, is how well true colors are displayed.

The Video Controller Card recommended by the AICC is a PCI local bus video card capable of graphics resolution of 1024 x 768 with 65K (65,536) colors. The use of the PCI local bus allows the video controller to run at a much higher data rate as opposed to the older 16-bit ISA bus. These cards are often referred to as video accelerator cards and they usually have high-speed video chips and on-board video memory. Video memory is an important factor when calculating video resolution and color depth. Standard VGA resolution with a color depth of 16 colors requires only 154 KB of memory; whereas, 1024 x 768 x 65,000 colors requires over 1.5 MB, and almost 2.5 MB is required for 16.7 million colors. Therefore, there should be a minimum of 2MB of video RAM available; 4-8 MB is becoming very common. The next video bus standard that has been established by Intel and is appearing on high-end pc systems is the Advanced Graphics Port (AGP). Many video card manufacturers are selling both a PCI and AGP version of the same card. The AGP bus is linked directly to the CPU and is for video cards only. In the future, AGP video cards will most likely replace

PCI video cards, but PCI video is adequate for today's courseware. Video accelerator cards are a must for multimedia-based applications running in an Windows environment to obtain acceptable graphics and video performance.

Another consideration for future multimedia courseware is a video card with hardware MPEG (Moving Picture Experts Group) playback. MPEG has become a compression standard for audio, video and data supported by the International Standards Organization (ISO). MPEG compression allows for large digitized video clips to be stored and transmitted with little degradation in quality. As the use of CBT grows and delivery platforms gain capability, the addition of video clips will become more common.

5.2.5 Sound

The AICC recommendation is a MPC (Multimedia PC) II 16-bit sound card, which is the industry standard for Windows-based sound. The sound card is not as critical as other components of the system, but should be as compatible as possible with the various application software running on the platform. It should also support the most common methods of sound compression, ADPCM and MPEG, which are required to economize on disk space. As more multimedia are incorporated into CBT, the audio requirements will increase. As that happens, a 32-bit sound card will likely to be required and will most likely become the standard for Windows Based sound.

5.2.6 CD-Rom Player

If a CD-ROM is required, the AICC recommendation is that it be MPC II compliant. The unit should be at least 16X speed. This rate provides enough performance to handle 15-frames/sec, 320 x 200-resolution video, which is typical of video-intensive applications today. CD-ROMs are relatively inexpensive and are also becoming necessary as more and more software is being delivered in CD-ROM format. A faster CD-ROM, such as a 24X speed, will improve playback of video, especially MPEG.

5.2.7 Networking

If networking is an option, AICC recommends a PCI network card capable of 10 MB/s and 100 MB/s. Although 10 MB/s networks are currently in place in many network installations, many cards are capable of both rates and should be acquired for future implementation.

5.2.8 Other Miscellaneous Components

Other miscellaneous hardware components necessary for system operation, but not critical in terms of discussion are listed below.

- Standard QWERTY Keyboard
- Mouse (any windows compatible xy pointing device may be used, such as a trackball, touch pad, pen pointer, etc.)
- 3.5", 1.44MB Floppy Drive
- (2) RS232C Serial and (1) Parallel External Ports

5.3 Hardware Platform Recommendation Summary

As mentioned above, the selected hardware platform for CBT will depend upon its intended primary usage. However, a summary of the components discussed above for a nominal new platform for CBT is listed in Table 5.1.

Table 5.1. Nominal Courseware Delivery Hardware Platform

CPU	200 MHz (or faster) Intel Pentium-based, w/ISA/PCI bus
RAM	64 MB
Floppy Drive	3.5", 1.44 MB
Video	PCI Local Bus Controller w/2 MB (or more) video memory
Video Display	20" non-interlaced, multisync, SVGA w/ min. Refresh rate of 75 Hz and bandwidth of 85 MHz (min.), dot pitch of .26 mm
Video Resolution	1024 x 768 with 16 bit color (65k colors)
Sound Card	16 bit, MPC II compliant
Keyboard	US QWERTY
Pointing Device	Windows compatible mouse (or other device)
Ports	(2) RS232 Serial, (1) Parallel
CD-ROM (optional)	16X
Network Card (optional)	10/100 MB/s Ethernet

6.0 COMPUTER MANAGED INSTRUCTION (CMI)

Computer Managed Instruction (CMI) is a software application tool which can manage both courseware and students in a training environment. A CMI system generally consists of the following five components, which can be tailored and used in a variety of ways:

- Course structure development,
- Test development and administration,
- Student rostering,
- Student assignment management,
- Student data collection and management.

The course structure development component is the core of the CMI system. This feature allows the instructor to build a variety of courses from basic modules covering theory, application and simulations, which best suit the particular needs or requirements of the class and students. The instructor can build a hierarchy of lessons which encompass a course, assign various attributes and objectives to each course and determine the relationships and paths between each lesson.

The test development and administration offers the capability to provide on-line (computer) and off-line (paper) testing of the student's mastery of the lesson. The results can be tracked and used to automatically prevent the student from proceeding until successful completion of a lesson in the case of student-paced instruction. Examinations are an essential element to NDI training because certification is based on testing results. IMCBT material using the performance goal approach employs testing as part of the progression through the course. A student must answer material correctly to proceed. Following completion of a training package a certification test may be given. The IMCBT courseware should contain potential questions to be used for the appropriate training level. A "Testing" section as mentioned under IMCBT training courseware, Section 4.0, above would provide such questions. The sources for questions may come from existing questions used in the Air Force NDI Training school, the Air Force ALC courses, ASNT, or other training sources. The testing may be performed using hard copy or using the computer for the testing sequence. The ETS software from Karta Technology is an example which could be included in IMCBT training courseware.

The student rostering component supports registration or enrollment of a student in a course, providing the basic student data (including demographic if desired). Reports can be generated which include course rosters, current assignment lists, resource utilization, student performance history and course maps.

The student assignment management component can perform the day-to-day functions of the lesson assignment and performance recording. It provides for the student logon, student progress for the current lesson, student's next lesson and initiation of that assignment.

The data collection component provides automated collection and management of data. This component also provides for both standard and ad-hoc reports on the data collected. The

typical data collected might include: lesson and course summary data, test item response and student performance data.

Student records can be maintained on a stand alone platform, but would have to be transferred via floppy disk to a central source for long-term maintenance and consolidation. If the platforms have networking capability, then student records can be maintained in a central source. This would have the advantage of not requiring manual transfers of data. Records could be examined and maintained instantaneously in a central location.

All aspects and offerings of a complete CMI tool may not be necessary or desired for student enrollment and administration. However, the CMI offers a quick and easy way to assemble a variety of courses from the basic modules. The student tracking portion can be utilized as desired or tailored to meet current requirements in that area.

7.0 CONCLUSIONS AND RECOMMENDATIONS

It has been shown in the development of the INSPECT prototype IMCBT for NDI personnel that the potential for better learning, i.e., higher and more retention of material, and lower training costs does exist. The results of the questionnaire given to both AF and industry professionals and to high school students show that, in general, the INSPECT CD prototype was appealing and could be a useful teaching tool, especially in combination with existing teaching methods. The survey results show that the style and presentation of the CBT were "on track," especially the use of audio and motion graphics (animations), and the quality of the art work; however, the general feeling was the prototype lacked sufficient depth and coverage for real examination. The prototype did point out some "bugs" and objectionable items as observed from the reviewers: hard-to-read text, navigation troubles, out-of-sync audio and lack of documentation. These are easily fixed items and demonstrate the usefulness of reviewing a prototype of the CBT.

The cost benefit numbers researched during this program are impressive, but are referenced from general studies in the use of CBT. Without further and more extensive review of the CBT package, the information supplied is not sufficient to determine the accurate cost savings and benefits to this particular implementation of IMCBT. To determine the actual cost savings and benefits of the use of IMCBT for NDI personnel, the issues should be addressed by the total completion of the prototype CBT module into a complete lesson for at least one method of NDE. The "bugs" and objectionable items should be fixed. In addition, the glossary, expert and simulation sections should be expanded to include what might actually be used in a teaching situation. The eddy current (EC) method for which INSPECT was built remains an excellent test bed. This method has some of the most complicated physics principles for which animation greatly aids learning. EC is a widely employed inspection methodology with a number of variations.

The researched benefits and the responses from the INSPECT survey provide adequate justification for this further investment. When the package is complete for one NDE method, training sessions should be run with and without the CBT to quantify and compare such items as test scores, time to complete the course and reaction to the use of CBT. In addition, the CBT should be tried with a variety of teaching methods to determine which usage works the best, with whom and when, i.e., student paced, with instructor, theory vs. intermediate and advanced material, just-in-time training, etc. The results of this study should determine how to proceed with all NDE methods.

8.0 REFERENCES

1. AICC, "Courseware Delivery Stations: Hardware," *AICC Guidelines and Recommendations*, AGR 002, Version 7.0, 14 Jan 1998.